

PROSTHETIC FOOT

This application is a continuation of application Ser. No. 07/977,806 filed Nov. 17, 1992, now U.S. Pat. No. 5,443, 528, and priority is claimed thereto.

I. BACKGROUND OF INVENTION**A. The Field of the Invention**

This invention relates to the field of prosthetic foot and leg devices, particularly those providing a springing action, torsional and lateral and medial movement, vertical shock absorption and sensory feedback to help the prosthetic foot approximate the response and performance of a natural foot.

B. The Background Art

Various prosthetic feet in the prior art have been designed with spring components intended to store energy when the foot is placed on the ground and to release it and provide a lift or thrust as the foot is removed from the ground again to aid in the patient's gait. Examples of this are Abrogast et al., U.S. Pat. No. 4,865,612 (Issue Date: Sep. 12, 1989) and Shorter et al., U.S. Pat. No. 5,116,383 (Issue Date: May 26, 1992) which are hereby incorporated by reference. Other prosthetic feet in the prior art have used an ankle joint intended to accommodate terrain and walking conditions. Example of this are Voisin, U.S. Pat. No. 4,718,933 (Issue Date: Jan. 12, 1988) and Delp, U.S. Pat. No. 4,306,320 (Issue Date: Dec. 22, 1981) which are hereby incorporated by reference. Poggi et al., U.S. Pat. No. 4,645,509 (Issue Date: Feb. 24, 1987), which is hereby incorporated by reference, disclosed a prosthetic foot which could accommodate uneven terrain by utilizing separate individual toe portions as part of a monolithic cantilever beam. Other prosthetic feet in the prior art have employed multiple springs, including multiple leaf springs, in an attempt to approximate the response and performance of a natural foot. Examples include Merlette, U.S. Pat. No. 4,959,073 (Issue Date: Sep. 25, 1990); Phillips, U.S. Pat. No. 4,547,913 (Issue Date: Oct. 22, 1985); Phillips, U.S. Pat. No. 4,822,363 (Issue Date: Apr. 18, 1989); and Phillips, U.S. Pat. No. 5,037,444 (Issue Date: Aug. 6, 1991), each of which is hereby incorporated by reference.

No prosthetic foot in the prior art has been completely successful in approximating the performance and response of a natural foot, however. Those prior art prosthetic feet which did not utilize a spring-loaded heel, such as Voisin and Delp, experienced a lag or deadness after the patient placed the heel on the ground and began to roll the foot forward during the gait cycle. This was due to the necessity of loading a spring in the toe section after the patient's weight had been placed on the ground. The response and feel of a natural foot cannot be achieved unless the spring(s) are loaded as the patient's weight is placed on the ground rather than after. Prior art prosthetic feet that utilized a spring-loaded heel which operated on a spring separate from a spring in the toe section, such as the Phillips patents and Merlette, effectively stored energy in the heel, but were ineffective in transferring the energy from the heel to the toe portion of the prosthetic foot as the foot rolled forward during the gait cycle. These devices still required separate loading of a spring in the toe section. As a result, the patient noticed a distinct and unnatural lag or hesitation in rolling the foot forward during the gait cycle, giving the foot an unnatural feel and possibly causing an uneven stride. Another problem with multi-spring or multi-component prosthetic feet is that the fasteners, such as bolts, used to

fasten the various components to each other quickly wear the spring material resulting in short useful life. Composite material such as graphite laminate, generally recognized as one of the best materials currently available for manufacture of prosthetic feet, is particularly susceptible to this. Two Phillips patents (U.S. Pat. Nos. 4,822,363 and 5,037,444) illustrate the use of problematic fasteners. Reinforcement of the spring material sufficient to reduce this wear to a tolerable level results in thickening of the spring and loss of its responsiveness. The use of spring steel to construct the prosthetic foot reduces the undesirable wear but provides a heavy prosthesis and quickly becomes brittle and breaks during continuous use. Aluminum can be used to construct a lightweight prosthetic foot, but it has insufficient springiness and resiliency to provide a prosthetic foot which accomplishes the goals of the present invention. Those prior art prosthetic feet which utilized a one-piece spring throughout the foot, such as Shorter et al., experienced a lag or deadness after the patient placed the heel on the ground and began to roll forward because the spring design was not suited to absorb and store sufficient energy in the heel and then transfer it to the toe section, thus requiring the toe section to be loaded after the patient's weight had been placed on the ground. Some prior art prosthetic feet, such as Phillips (U.S. Pat. No. 4,547,913) could accommodate torsional movement about the longitudinal axis of the shin portion, but the shape of the shin portion was designed for spring strength and breaking strength, not torsional movement, and the torsional stiffness of the shin section was not adjustable. Finally, prosthetic feet in the prior art lacked any effective means for absorbing and storing energy when vertical force is applied to the foot. Prior art prosthetic feet which utilized a plurality of springs, such as Phillips, tended to rock under vertical load as the load was distributed separately to the springs. Prior art prosthetic feet with a single spring member and a foam heel tended to absorb vertical load either in the spring member or in the foam heel, but not in both. Thus, the prior art exhibited a need for a prosthetic foot which approximates the performance and response of a natural foot by using a spring-loaded heel section integral with a spring-loaded toe section and capable of transferring energy from the heel to the toe during the gait cycle without lag or hesitation, a one-piece prosthetic foot without fasteners that may wear the spring material, a prosthetic foot that can accommodate angled or uneven terrain, a prosthetic foot capable of accommodating lateral and medial movement, a prosthetic foot capable of accommodating torsional movement about the longitudinal axis of the shin with means for adjusting torsional stiffness and a prosthetic foot capable of evenly absorbing and storing energy when vertical force is applied to the foot.

II. SUMMARY OF THE INVENTION

It is an object of the invention to provide a prosthetic foot which stores energy upon heel strike with weight applied in the gait cycle, transfers energy during foot roll-forward to mid foot (flat foot) and to toe-off in the gait cycle, and releases energy at toe-off to provide a propelling lift or thrust to the prosthetic foot to aid in achieving a natural gait. It is a further object of the invention to provide a prosthetic foot which uses a heel extension section integral with a forefoot extension section and capable of transferring energy from the heel to the forefoot during the gait cycle without lag or hesitation. It is a further object of the invention to provide a one-piece prosthetic foot in the form of a continuous coil spring that will eliminate the need for fasteners that may